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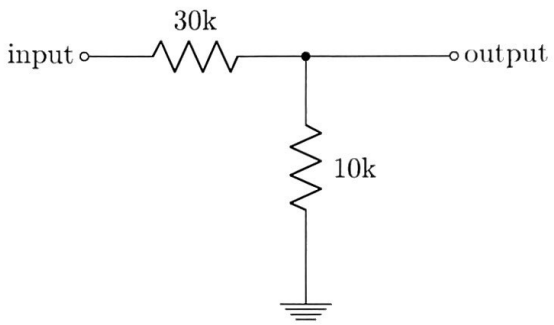
Electronics for Scientists

Exam 1: Resistors, capacitors, and diodes

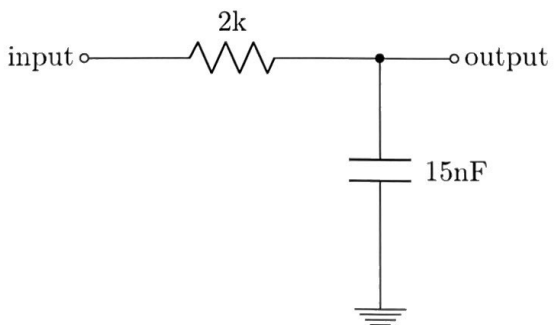
Instructions

Complete the following exercises to the best of your ability. Do not forget your units and show your work! Answers without units or supporting work will be graded incorrect.

1. Calculate and draw the Thévenin equivalent circuit of the below circuit. If a 10 V DC voltage is applied to the input, what is the output voltage, assuming no load across the output? What is the output voltage if there is a 10k load across the output? [20 points]



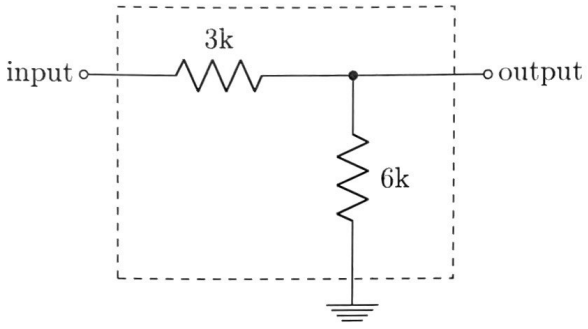
2. A student constructs the below circuit. Is the circuit a highpass or lowpass circuit? Specifically state how you determine this answer, without invoking "I memorized these or wrote it on my equation sheet." What is the $f_{3\text{dB}}$ of the circuit? If a 12 V RMS AC voltage source with a frequency of 10 kHz is connected to the input, what is the peak voltage measured by the student at the output? [20 points]



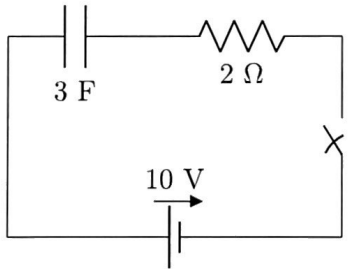
The output voltage from RC highpass and lowpass filters are given by:

$$\text{highpass} : V_{\text{out}} = \frac{\omega RC}{\sqrt{1+\omega^2 R^2 C^2}} V_{\text{in}} \qquad \text{lowpass} : V_{\text{out}} = \frac{V_{\text{in}}}{\sqrt{1+\omega^2 R^2 C^2}}$$

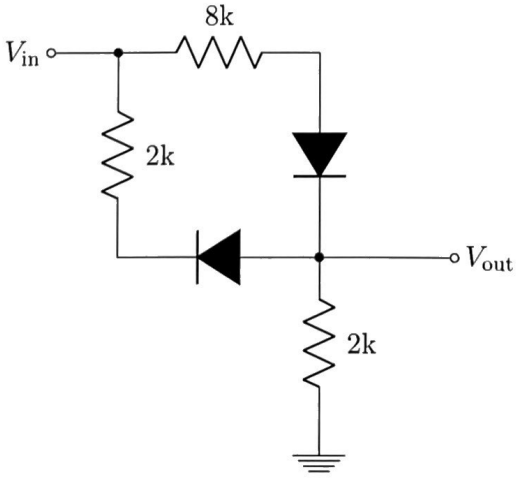
3. The circuit diagram of the "1/3 voltage dividing box" sold by Crummy Circuits, Inc. is shown in the diagram below. The circuit has an identified input, output, and ground. What is the input and output impedance of the circuit? It may be helpful to create some test circuits using a test resistor and voltage source. If you do, use a 3k test resistor and 10 V DC source in your calculations. *Because there are no frequency-dependent components in the circuit, input and output resistance would probably be better terms.* [20 points]



4. The capacitor in the below RC circuit is initially uncharged when the switch is closed. What is the voltage across the capacitor 5 seconds after closing the switch? What is the voltage across the capacitor 20 seconds after closing the switch? 20 seconds after closing the switch, the switch is opened again. What is the voltage across the capacitor 10 seconds after the switch is reopened (30 seconds from the initial closing of the switch)? *Be careful and examine the circuit closely.* [20 points]



5. A 10 V AC signal is applied to the input of the below circuit. Sketch the output voltage as a function of time. To simplify the math, ignore the voltage drop across the diodes. [20 points]



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Test 1

Problem 1

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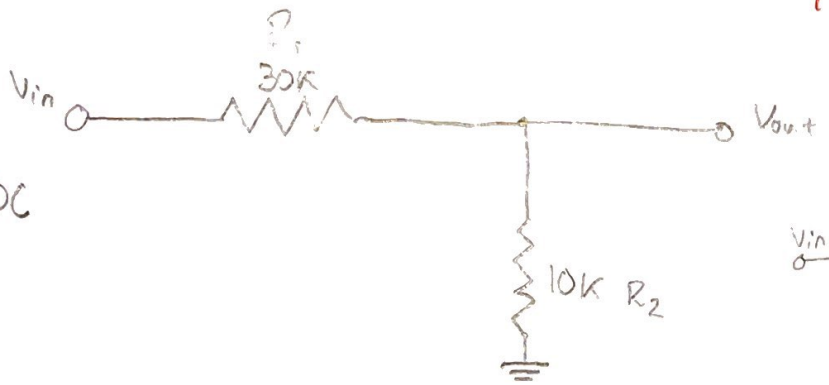
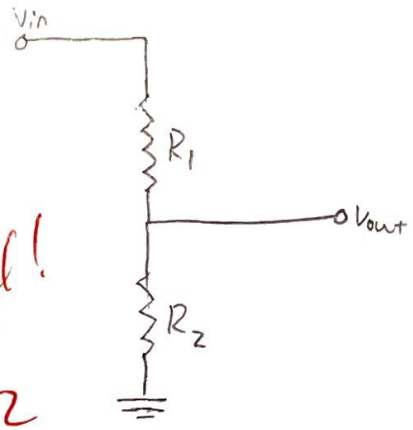


$V_{in} = 10$ V DC



a.)

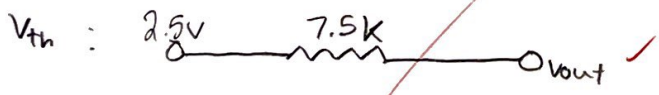
$$V_{Th} = \frac{R_2}{R_1+R_2} V_{in} \qquad R_{Th} = \frac{R_1 R_2}{R_1+R_2}$$

no load!

$$V_{Th} = \frac{10k}{10k+30k} V_{in} = \frac{1}{4} V_{in} \quad \therefore \quad V_{Th} = 2.5 \text{ V} \checkmark \quad -2$$

$$R_{Th} = \frac{R_1 R_2}{R_1+R_2} = \frac{10k(30k)}{10k+30k} = \frac{300k}{40k} = 7.5k \checkmark$$

Thevin Equivalent



$10V - I(30k) - I(10k) = 0$

$10v - I(30k + 10k) = 0$

$I(40k) = 10V$

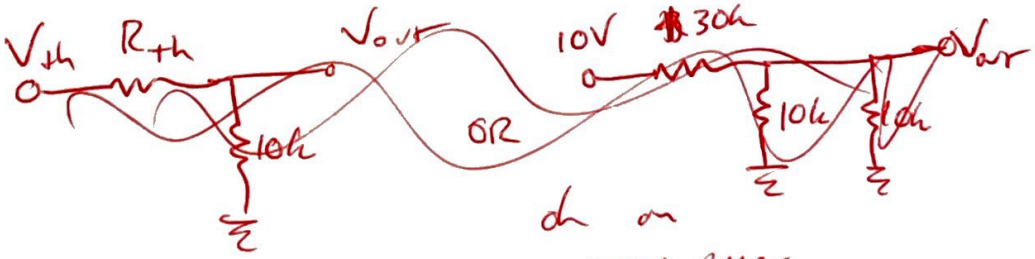
$I = \frac{10v}{40k}$

$I = 0.25 mA$

$2.5V - I(7.5K) = V_{out}$

$2.5V - (0.25mA)(7.5K) = 0.625V$

$V_{out} = 0.625$ V



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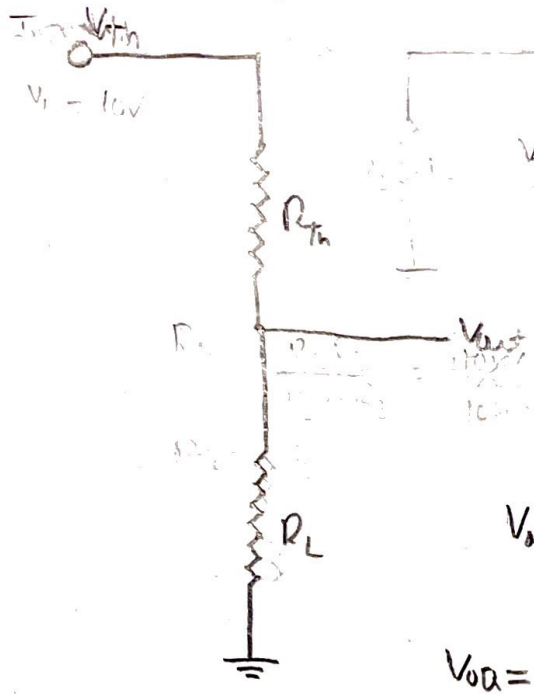
Test 1

Problem 1



VOLTAGE DIVIDER !!!!

$V_{th} = 2.5V \Rightarrow V_{in}$

$R_{th} = 7.5K \Rightarrow R_1$

$R_L = 10K \Rightarrow R_2$

$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$$

$$V_{OQ} = \frac{10k}{10k + 7.5k}(2.5V) = 1.428 \text{ volts}$$

$V_{out} = 1.43V$ ✓

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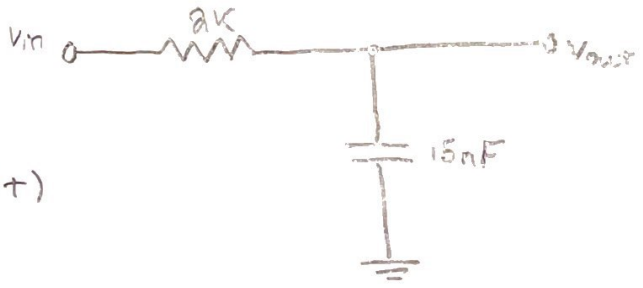
Test 1

Problem 2



$V = A\sin(2\pi \cdot f \cdot t)$

a.) Highpass Filter

This is a highpass filter because at high frequencies the capacitor becomes meaningless, thus creating a thevenin equivalent. a short so $V_{out} = 0$ At low frequencies the capacitor would be first for a low pass filter where the voltage would charge up the capacitor instead of run through like it does here. cutting off ground from circuit -2

$f = \frac{1}{2\pi RC}$

b.) f_{3dB} $\omega = 2\pi f$

$f = 10\ kHz$
$R = 2k$
$C = 15nF$

$f_{3dB} = \frac{1}{\omega RC} = \frac{1}{2\pi(10kHz)(2k)(15\times10^{-9}F)} = 0.53\ Hz$ -1

$f_{3dB} = 0.53\ Hz$ 5.3kHz

c.) Peak : Rms $\cdot\sqrt{2}$

$P_v = 12v(\sqrt{2}) = 16.9v \approx 17v$ ✓

$P_v = 17V$

$\omega = 2\pi \cdot (10kHz) = 62831.9\ Hz$ ✓

$V_{out} = \frac{\omega RC}{\sqrt{1+\omega^2R^2C^2}} = \frac{6.28\times10^4\ Hz(2k)(15nF)}{\sqrt{1+(6.28\times10^4Hz)^2(2k)^2(15nF)^2}}$

$V_{out} = 0.88V$

Peak V = 17v
$V_{out} = 0.88V$ ok

wrong, but if was a highpass —

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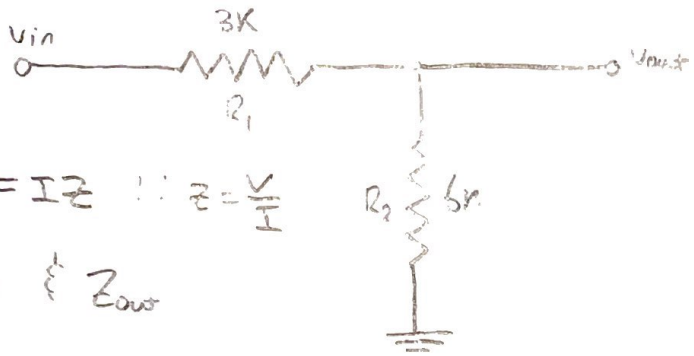
TEST 1

Problem 3



VOLTAGE DIVIDER !!!

$V_{OUT} = \frac{R_2}{R_1+R_2} V_{in}$

$V_{in} = 10V$

$V=IR \;\therefore\; V=IZ \;\therefore\; Z=\frac{V}{I}$

Z? $\quad Z_{in}$ & Z_{out}

$$V_{out} = \frac{6k}{3k+6k}(10V) = \frac{6K}{9k}(10V) = 6.66V$$

$$10V - I(3k) - I(6k) = 0$$

$$10V - I(3k) = 6.66V \;\therefore\; I(3k) = 3.33V$$

$$I = \frac{3.33V}{3k} = 1.11\times10^{-3}A$$

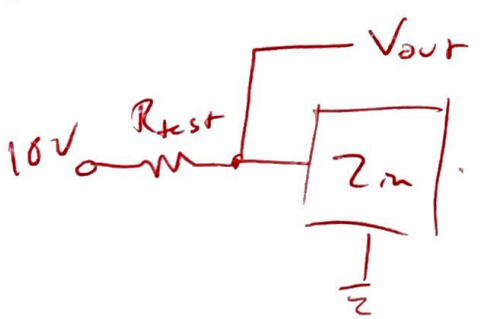
$V_{in} = 10V \;\therefore\; Z_{in} = \frac{V_{in}}{I} = \frac{10V}{1.11\times10^{-3}A} = 9009.01\,\Omega$

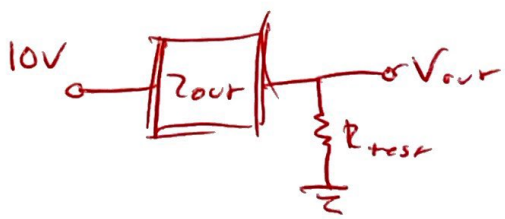
$V_{out} = 6.66V \;\therefore\; Z_{out} = \frac{V_{out}}{I} = \frac{6.66V}{1.11\times10^{-3}A} = 6000\,\Omega$

$Z_{in} \approx 9000\,\Omega$ ✓

$Z_{out} \approx 6000\,\Omega$

-10





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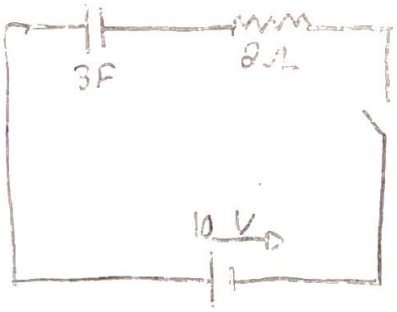
Test 1

Problem 4



$V_{out} = V_f(1 - e^{-t/RC})$

a.) 5 seconds after

$R = 2\Omega$
$C = 3F$
$t = 5s$
$V_F = -10V$

$V_{out} = (+10V)(1 - e^{\frac{-5}{2 \cdot 3}}) = -5.65V$

$V = +5.7V$

b.) 20 seconds after

$R = 2\Omega$
$C = 3F$
$t = 20s$
$V_F = -10V$

$V_{out} = (-10V)(1 - e^{\frac{-20}{2 \cdot 3}}) = -9.64V$

$V = +9.6V$

c.) 10 seconds after opened

$R = 2\Omega$
$C = 3F$
$t = 10s$
$V_F = -9.6V$

$V_{out} = (-9.6V)(1 - e^{\frac{-10}{2 \cdot 3}}) = -7.78V$

$V = -7.8V$

-3

no discharge circuit!

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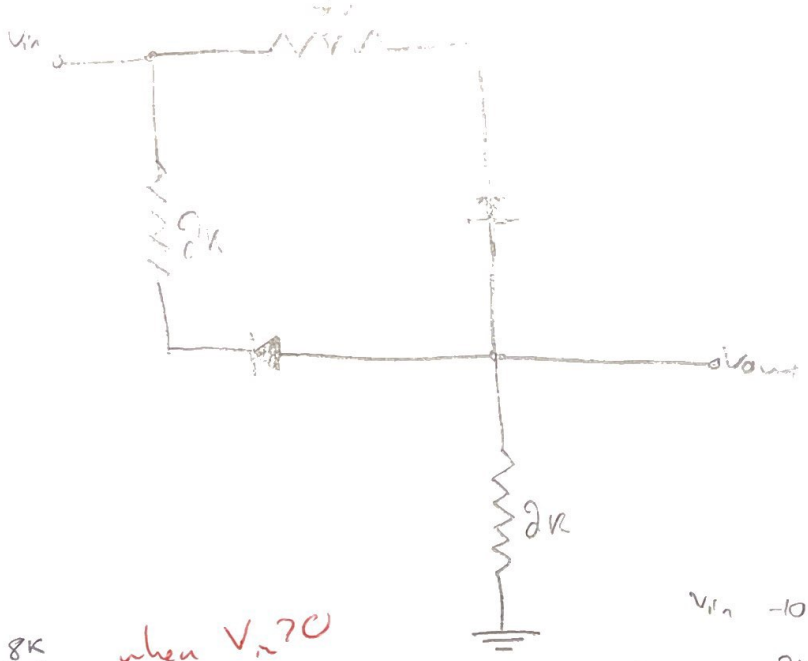
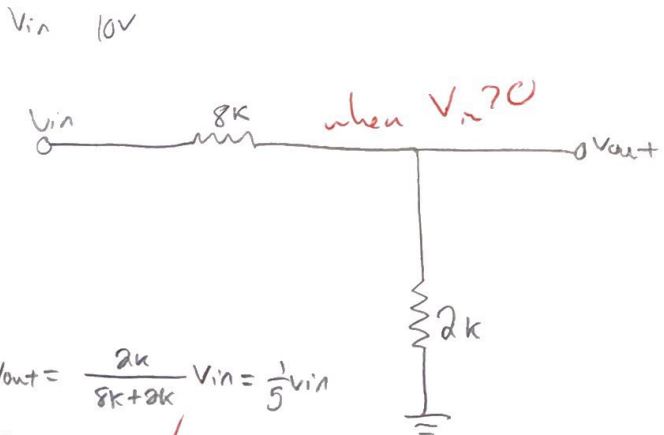
Test 1

Problem 5 1

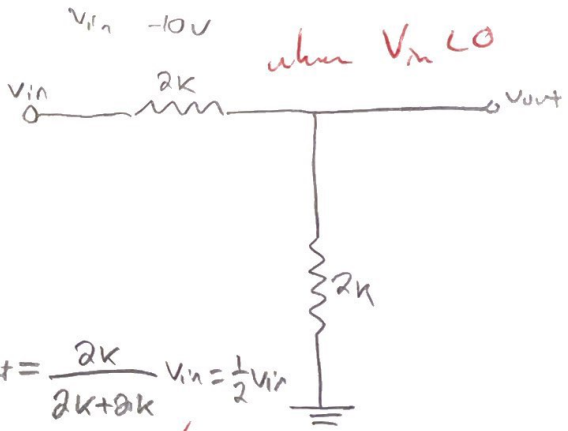


$V_{in} = 10V$



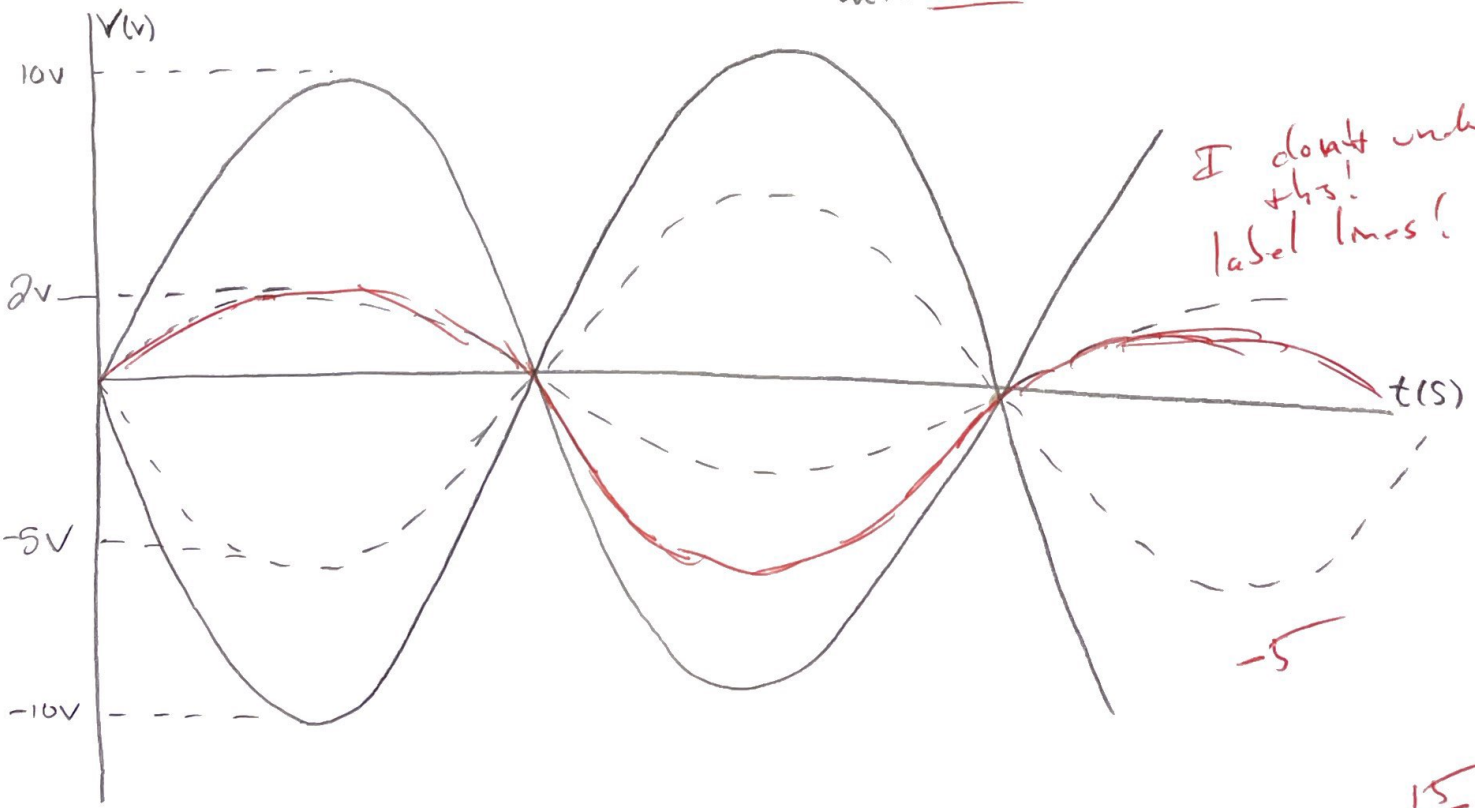
$V_{out} = \frac{2k}{8k+2k} V_{in} = \frac{1}{5} V_{in}$

$V_{out} = 2V$ ✓



$V_{out} = \frac{2k}{2k+2k} V_{in} = \frac{1}{2} V_{in}$

$V_{out} = -5V$ ✓



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